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Algebra is often described as the “gatekeeper” to higher education and future employment because it has served as a filter by screening out large numbers of students, rather than as a pump helping to develop students’ mathematical competence and access to higher education (Ladson-Billings, 1998 and Moses & Cobb, 2001). “Algebra…can mean the difference between menial work and high-level careers” (Helfand, 2006, p. 1). The National Council for Teachers of Mathematics position statement *Algebra: What, When, and for Whom* reads: “Knowing algebra opens doors and expands opportunities, instilling a broad range of mathematical ideas that are useful in many professions and careers. All students should have access to algebra and support for learning it” (NCTM, 2008, paragraph 1).

Accordingly, across the country, schools are instituting “Algebra-for-all” programs so that all students develop algebraic thinking skills before they graduate high school. However, the statistics on failure in algebra courses are staggering. In 2004, in the Los Angeles School District, “48,000 ninth-graders took beginning algebra; 44% flunked, nearly twice the failure rate as in English. Seventeen percent finished with Ds. In all, the district that semester handed out Ds and Fs to 29,000 beginning algebra students… Among those who repeated the class in the spring, nearly three-quarters flunked again…It triggers dropouts more than any single subject” (Helfand, 2006, p. 1). In Chicago, the school district recently published a study indicating that failure in algebra is increasing significantly (Viadero, 2009). In response, Michael Lach, the director of the office of high school teaching said “It’s not surprising that you’re going to see an increase in [failure] rates if you raise the instructional requirements and you don’t raise the supports.” (Viadero, 2009, paragraph 8). Furthermore, while mathematical proficiency of students has steadily increased on the National Assessment of Educational Progress over the last 17 years, a significant gap has remained, or increased, for students of low socio-economic status and minorities (National Center for Education Statistics, 2008).

Students of algebra are desperately in need of support. Districts are responding by creating two- or three-year programs for algebra or having students take double periods of algebra, but the success rate is not changing significantly (Nomi & Allensworth, 2009). We can't teach algebra the same way repeatedly and expect different results. While there is some evidence that new curricula from projects such as the Connected Mathematics Program and College Preparatory Mathematics Program are improving students' success with algebra (i.e. Moseley & Brenner, 2009; Riordan & Noyce, 2001), there is controversy over its effects (i.e. Milgram, 1999), and students often continue to struggle with the ideas of algebra.

Technology to the rescue?

Research indicates that technology can facilitate the transition from arithmetic to algebra (Battista & VanAuken Borrow, 1998: Rojano & Sutherland, 1993; Tabach, Hershkowitz, & Arcavi, 2008). For instance, graphing calculators add significant power to learning (Gage, 2002 and Reznichenko, 2007). Virtual manipulatives can be effective tools in enhancing students' conceptual understanding (Bos, 2009; Suh, 2005; Zacharias, Olympiou, & Papaevripidou, 2008). Spreadsheets have been identified in research and algebra textbooks for over a decade as a potential, effective support for algebra learning. However, "their use in mathematics remains marginal" (Haspekian, 2005, p. 109). Multiple barriers exist to thwart teachers who might want to make use of the power of technology for learning.

Achieving the promise of technology to significantly impact learning remains elusive for the majority of schools. "The number of computers in public school classrooms was not adequate to use computers effectively for classroom instruction, and the classroom was not the main location in school where most students used computers…level of access was inadequate for educators to use computers effectively in classroom instruction" (NEA, 2008, p. 2). Bandwidth is a concern, computer access issues continue to apply, and many schools have restrictive Internet policies. With the exception of graphing calculators, access to technological tools for use in classrooms and effective professional development continue to be a significant issue for teachers.

The National Education Association (NEA) recommends that, in order to improve students' and educators' access to technology in the classroom, more wireless and portable technologies need to be available (NEA, 2008, p. 6). Two decades ago graphing calculators were introduced to school classrooms. Now they are ubiquitous in high school mathematics classes as prices have dropped from \$200 to \$45. This summer, Apple released the latest software for the iPhone and iPod Touch, which includes peer-to-peer interaction, connection to third party accessories (such as science probes), and other new capabilities. Comparable devices are sure to follow, ensuring lower costs and broader access. The pace of innovation for this technology is dizzying. In less than a year since the introduction of applications for the iPhone and iPod Touch, Apple reports that entrepreneurs have created over 70,000 applications and users have downloaded them over 1 billion times. The potential for one device to serve multiple purposes in education has arrived. The iPhone and iPod Touch is a graphing calculator, can do spreadsheets, will connect to third party devices, and can easily provide both video-based problem solving opportunities and access to virtual manipulatives.

What does this have to do with algebra?

"An error is not merely a failure by a student but rather a symptom of the nature of the conceptions which underlie his/her mathematical activity" (Balachef, 1984). Errors can result from simple carelessness or forgotten rules, such as 5 + 3 = 9. In this case, the student can quickly identify the mistake. Researchers have also found that some "some kinds of errors are widespread among students of different ages, independent of the course of their previous learning of algebra" (Demby, 1997). Some students make the same type of errors regardless of their experience with algebra, indicating common struggles that have more complex sources than simple calculation or memory errors. These errors can be due to misconceptions that reside deeper in a student's consciousness, a multifaceted structure that has naive or faulty assumptions inconsistent with accepted mathematical practices that can be stable and resistant to instruction (Anderson & Smith, 1987). Whether the error is part of a developmental process, that is, self-correcting as the student progresses through school, or a more pervasive type that is only corrected through a student's teacher-supported reflection, the importance is the immediate impact on students' understanding current content.

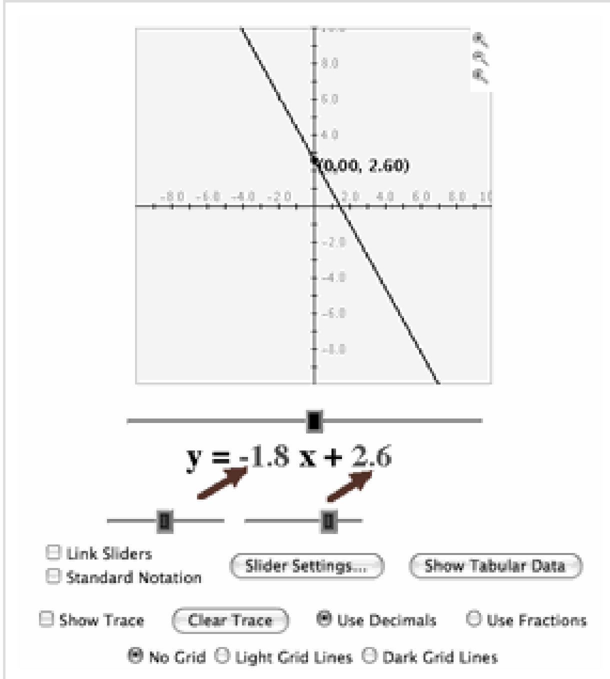
New handheld technology, if it is not reduced to uses such as the simple drilling of skills, can create opportunities for students to address misconceptions, construct meaning, and explore their thinking. Visual representation of ideas can facilitate students' thinking and understanding in ways not possible with pencil and paper. "Technology can impact mathematical activity through affecting the content and tasks of algebra as well as its teaching…Technology can change the nature of opportunities for the mathematical activities of conceptualizing, representing, generalizing, symbolic work, and modeling as well as for student roles" (Heid & Blume, 2008, pp. 58-59). Many of the technologies that have promise for supporting algebra learning currently exist on other platforms, such as science probes, spreadsheets, and web-based java applets. There is considerable research demonstrating graphing calculators and spreadsheets have positive impacts on learning in algebra (i.e. Calder, Brown, Hanley, & Darby, 2006; Ellington, 2003; Rojano, 1996). Spreadsheets can act as a bridge between arithmetic and algebra by helping students generalize patterns, develop an understanding of variable, facilitate transformation of algebraic expressions, and provide a space to explore equations (Haspekian 2005; Tabach, Hershkowitz, & Arcavi, 2008; Wilson, Ainley, & Bills, 2005). One of the key features of a spreadsheet is its dynamic ability to allow students to manipulate numbers and instantly see the impact of the change on formulas and structures of numbers. The core of algebra is an understanding of variables. Students have many misconceptions about what a variable represents (Kuchemann, 1981; Stacey & MacGregor, 1997). Use of spreadsheets can facilitate students' construction of understanding of the traditionally challenging concept of variables effectively.

In order to use spreadsheets, teachers typically need to reserve and take students to a school lab or get a laptop cart for the classroom. These resources are often in high demand at a school, encouraging one-day lessons rather than sustained engagement with the tool and the ideas that can be developed with the tool. Adapting tools such as spreadsheets to the iPhone, iPod Touch and similar technologies can solve many problems associated with access and use. Teachers can use handheld technologies on demand, for "just-in-time learning," when they identify teachable moments with individual students, small groups, or the whole class. "Mobile technologies provide an opportunity for a fundamental change in education away from occasional use of a computer in a lab towards more embedded use in the classroom and beyond" (Naismith, Lonsdale, Vavoula, & Sharples, 2004, p. 6).

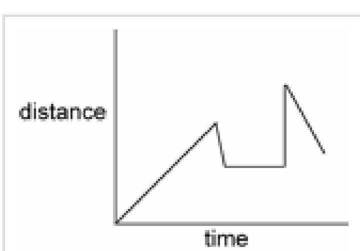
Although research in this area is only recently developing, virtual manipulatives and simulations with Java applets, such as those available through NCTM's Illuminations project (http://illuminations.nctm.org), Utah State's National Library of Virtual Manipulatives (http://nlvm.usu.edu), and Shodor's Interactivate (http://www.shodor.org/interactivate) can be powerful tools for learning (Crawford & Brown, 2003; Reimer & Moyer, 2005; Suh & Moyer-Peckenham, 2007). These are dynamic and engaging tools that facilitate students' construction of algebraic ideas, particularly in moving from concrete to abstract thinking (Bolyard & Moyer, 2003).

X	Y
3	7
0	1
-4	-7

An example of these virtual manipulatives is Shodor's "Slope Slider". Research shows that students have difficulty and develop misconceptions with many aspects of graphing lines, such as slope and y-intercept (Bishop, 2000; Swafford & Langrall, 2000; Walter & Gerson, 2007). To teach this concept, teachers typically use the traditional method of creating x,y tables, such as those in the figure at the right, to plug in points to graph lines one at a time and/or explain to students what m and b represent and how they change the graph of the equation $y = mx + b$. Instead, students with access to the Slope Slider (see below) can be asked "In the equation $y = mx + b$, how does changing the value for m or b impact the graph?" Students vary slopes and y-intercepts, seeing how their manipulation immediately impacts the line. Then, through discussions with their peers or teacher or writing an explanation, they solidify the algebraic ideas in their minds. With the Slope Slider, students can visually see how the number in front of x changes the slope by seeing an infinite number of lines plotted easily and quickly. When students are actively involved in constructing understanding, they are more likely to comprehend and retain algebraic concepts.



Students struggle with many aspects of algebraic graphing, including misconceptions about the meaning inherent in the axes of a graph (Friel, Curcio, & Bright, 2001). Research shows that students often take graphs as literal representations of the situation rather than graphical information (Monk, 1992). For instance, students confuse the image of a bicyclist riding up a hill with the relationship between time and distance in a graph. Science sensors, such as those developed by Vernier (http://www.vernier.com), can connect mathematics to real life situations. An understanding of axes can be developed as students use a temperature probe to examine the dynamic between time and temperature as a liquid warms or distance and time when motion detectors are used. One of the neat applications that can be used with Vernier's motion detector gives students the ability to create a random graph, such as the one below on the left, indicating a relationship between time and distance. Students need to move towards and away from the motion detector to recreate the graph. In small groups they discuss strategies and the relationship between time and distance. As they move back and forth, the handheld recreates their path to compare with the original graph, as in the figure at the right. They can repeat the activity until they can recreate the graph (or in the case of the figure at the right, explain why they cannot travel a great distance in no time).



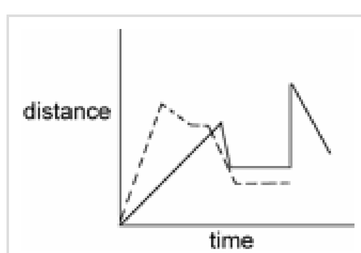


Figure 3:
Random Time Distance Graph

Figure 4:
Student Generated Time Distance Graph

Engaging students in authentic contexts and working collaboratively on important algebraic concepts with peers, such as the meaning of and relationship between axes, taps into the potential power of handheld technology. These sensors demand dedicated tools (i.e. Personalized Digital Assistants (PDA) or Calculator Based Laboratories (CBL)) or laptops to collect and make use of the data. The new version of software for the iPod Touch, released this summer, includes the capability to connect accessories such as Vernier sensors. The iPod Touch and similar future technologies can bring all of these uses to one easily accessible tool.

Another feature debuting for the iPod Touch this summer is **peer-to-peer** interaction. With this new capability, many of Interactivate's Java Applets and our other applications have interesting possibilities for students to engage with each other in exploring algebraic ideas. Rather than students struggling to understand algebra in isolation, we can tap into the power of students engaging in activity and conversation about algebraic concepts together. For example, a student might develop an algebraic equation that is represented graphically on the iPod Touch that another student might have to figure out. If both students had an iPod Touch, they could simultaneously be working on each other's equation. When students have to synthesize their knowledge of equations to create a challenging activity for a peer, they work at the highest level of Bloom's taxonomy of thinking. This type of activity would help students develop an understanding of the relationship between equations and graphs that is often a challenging concept in algebra.

Researchers with the Jasper Woodbury Project at Vanderbilt University found that video-based problem solving can stimulate engaged and thoughtful encounters with algebra. However, the technology only allowed the teacher or one student at a time to direct the playing of the video to find critical data. iPod Touch technology allows every student to have the power to manipulate the video to find data that they need from the situation, encouraging multiple approaches to a problem and student directed learning. One of the key struggles for students of algebra is their inability to differentiate between pertinent and extraneous data in real life situations and to choose appropriate algebraic tools to solve problems. Video-based problems can help develop those skills.

The bottom line is that we are at an exciting crossroads in handheld technology that is being driven by the extremely lucrative smart phone industry. In the quest to gain market share, there is tremendous competition to have the best gadgetry. Education can be the beneficiary of this corporate battle as new capabilities for tools such as Apple's iPod Touch create amazing potential for thinking about learning differently. The promised power of computers in the palm of your hand is a growing reality. This is great news for students of algebra in particular, who need visual supports to overcome challenges in developing their thinking and understanding. All we need is some ingenious educational software programmers to make the potential come to life.

So, get busy!!!

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